DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
S. W. STRATTON, Director

TECHNOLOGIC PAPERS OF THE BUREAU OF STANDARDS, NO. 50

[Issued September 25, 1915]

VISCOSITY OF PORCELAIN BODIES HIGH IN FELDSPAR

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The present work is a continuation of the experiments reported in Technologic Paper No. 30 in which the elongation of porcelain bars, subjected to a tensile stress of 5 pounds per square inch, was studied in connection with variations in composition and at several temperatures.

The object of the work was to determine the range of compositions showing greatest rigidity, at the highest kiln temperatures, information which should be useful in selecting bodies subject to minimum deformation in firing, and hence causing least loss in manufacture due to deformed ware.

The shape of the specimen was different from the one used in the earlier study and is shown in Fig. 1. This test piece proved to be very satisfactory. The compositions of the porcelains thus studied were intended to include higher feldspar contents and have been compiled in the following table:

TABLE 1

Composition of Bodies

Number	Clay	Feldspar	Flint	Number	Clay	Feldspar	Flint
	Per cent	Per cent	Per cent		Per cent	Per cent	Per cent
1	35	30	35	10	45	30	25
2	35	40	25	11	45	35	20
3	35	50	15	12	45	40	15
4	35	60	5	13	45	50	5
5	35	65	.....	14	45	55	.....
6	40	30	30	15	50	30	20
7	40	40	20	16	50	40	10
8	40	50	10	17	50	45	5
9	40	60	.....	18	50	50	.....

The clay content was made up of North Carolina kaolin, Georgia kaolin, and Tennessee No. 3 ball clay in the ratios of 5 : 1 : 1. The feldspar used was an average grade of potash spar, and was the same used in the previous work. The bodies were prepared by grinding wet in the ball mill and filter pressing. Plaster molds were used in pressing the specimens. After the pieces were dry, fine shrinkage marks were made on them 4 inches apart. All of the specimens were first burned to cone 10. The fire-clay load pieces to be attached to the lower end of the specimens were made at first to weigh 5 pounds, but it was found that this weight was entirely inadequate, since no deformation was obtained at all. Burns were made then with pieces giving 7.5 and finally 14.5 pounds per square inch. This weight was adopted as the standard condition for this series.

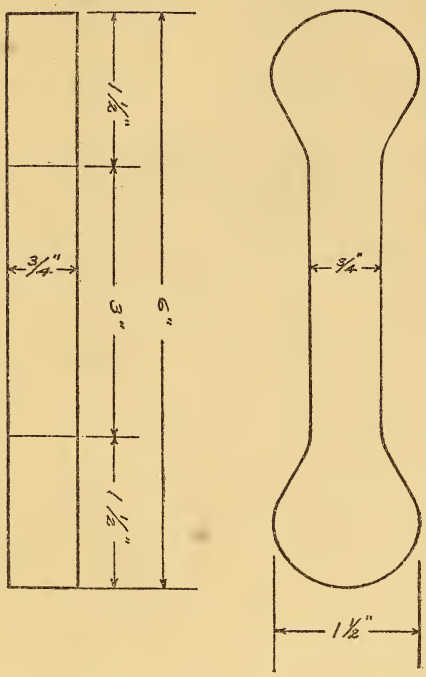

FIG. 1.—*Shape of test piece used in deformation experiments*

This shows clearly that the bodies previously studied, containing from 10 to 25 per cent of feldspar, show far less resistance to deformation under tensile stress than the present series with higher feldspar contents. This would appear to be logical from the viscous nature of the feldspar. Several runs, made below 1275° C, showed contraction; elongation due to softening was first observed at this temperature. It is quite probable that contraction and elongation practically neutralized each other within this temperature region. The pieces were hung from fireclay grids, the weight pieces attached and the kiln brought to the desired temperature at the rate of 30° C per hour. All bodies were vitrified and nonabsorbent. The lengthening of the pieces is expressed in terms of the length after the biscuit burn at cone 10.

RESULTS.

The results obtained are compiled in Table 2, and for bodies Nos. 8 to 18 are shown graphically in Figs. 2, 3, and 4. In the 35 per cent clay series a number of pieces were found to be broken at the higher temperatures, indicating that with low clay content low tensile strengths are obtained. This is to be expected, since

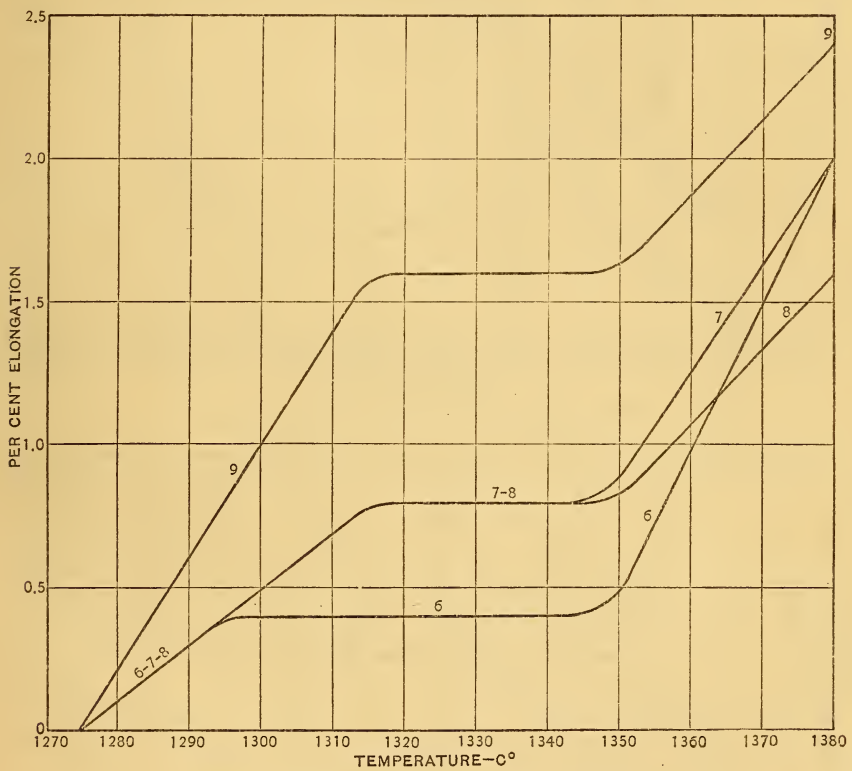

FIG. 2.—*Elongation of 40 per cent clay series*

in the previous series a load of 5 pounds per square inch was sufficient to bring about decided deformation. The results, although incomplete, bring out quite clearly the fact that with low clay content high percentages of feldspar are effective in reducing the rigidity or viscosity of the body. At the temperatures involved such bodies are far more subject to deformation than those having a higher clay content.

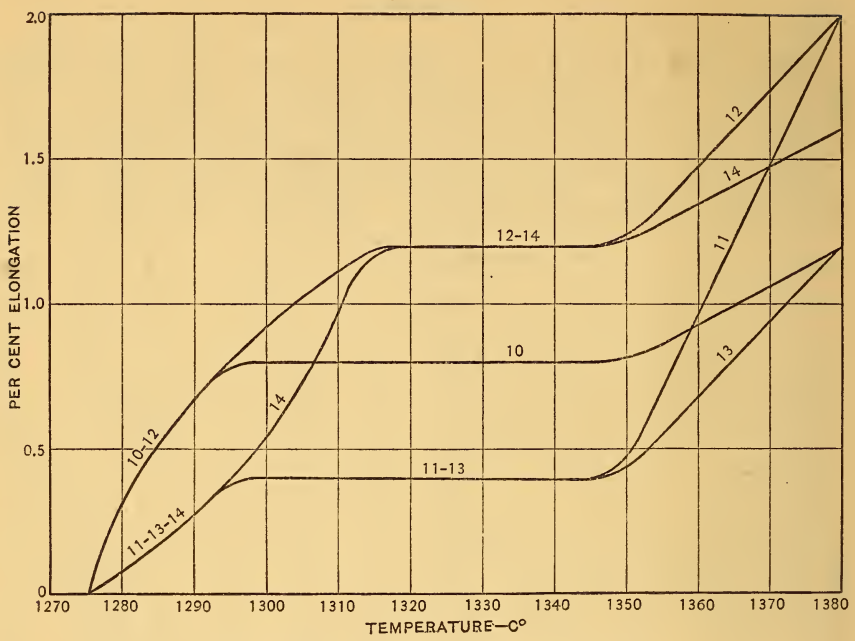

FIG. 3.—*Elongation of 45 per cent clay series*

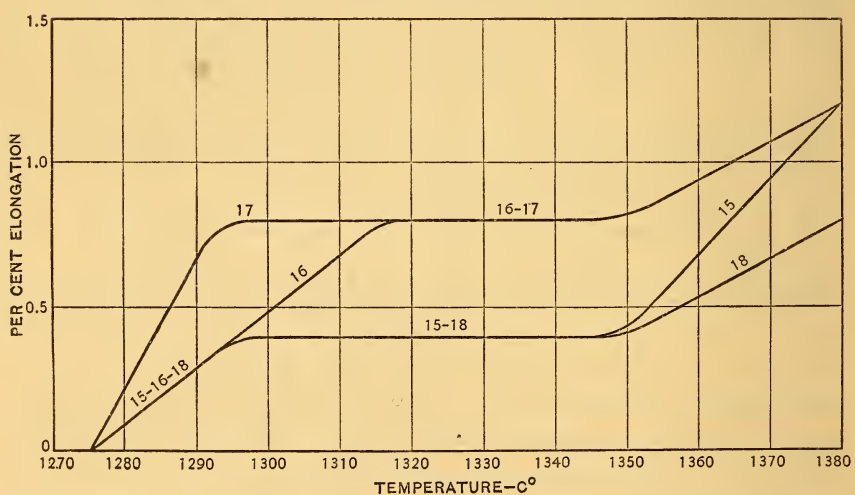

FIG. 4.—*Elongation of 50 per cent clay series*

TABLE 2

Elongation Measurements

Number	Biscuit length	Length, 1275°	Length, 1295°	Length, 1315° 1320°	Length, 1345° 1350°	Length, 1380°	Elong., 2175°	Elong., 1295°	Elong., 1315° 1320°	Elong., 1345° 1350°	Elong., 1380°
							Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1	2.56	2.56	2.56	2.62	2.66	Broke.	0.0	0.0	2.3	3.9	.....
2	2.56	2.57	2.59	2.62	Broke.	.....	.4	1.2	2.3	.....	.....
3	2.48	2.48	2.49	2.50	2.54	Broke.	.0	.4	.8	2.4	.....
4	2.51	2.51	2.53	Broke.	.....	.....	.0	.8	.....	.....	.....
5	2.51	2.51	2.53	2.55	Broke.	.....	.0	.8	1.6	.....	.....
6	2.50	2.50	2.51	2.51	2.51	2.55	.0	.4	.4	.4	2.0
7	2.49	2.49	2.50	2.51	2.51	2.54	.0	.4	.8	.8	2.0
8	2.48	2.48	2.49	2.50	2.50	2.52	.0	.4	.8	.8	1.6
9	2.50	2.50	2.52	2.54	2.54	2.56	.0	.8	1.6	1.6	2.4
10	2.46	2.46	2.48	2.48	2.48	2.49	.0	.8	.8	.8	1.2
11	2.49	2.49	2.50	2.50	2.50	2.54	.0	.4	.4	.4	2.0
12	2.46	2.46	2.48	2.49	2.49	2.51	.0	.8	1.2	1.2	2.0
13	2.44	2.44	2.45	2.45	2.45	2.47	.0	.4	.4	.4	1.2
14	2.46	2.46	2.47	2.49	2.49	2.50	.0	.4	1.2	1.2	1.6
15	2.45	2.45	2.46	2.46	2.46	2.48	.0	.4	.4	.4	1.2
16	2.44	2.44	2.45	2.46	2.46	2.47	.0	.4	.8	.8	1.2
17	2.43	2.43	2.45	2.45	2.45	2.46	.0	.8	.8	.8	1.2
18	2.44	2.44	2.45	2.45	2.45	2.46	.0	.4	.4	.4	.8

From the observations upon the 40 per cent clay series it appears that the greatest degree of softening is reached with 60 per cent feldspar (no flint). The presence of flint increases the viscosity. Of bodies Nos. 6, 7, and 8 the ones containing 30 and 40 per cent of feldspar seem to reach about the same degree of viscosity at the maximum temperature. The greatest rigidity at the highest temperature seems to be shown with a feldspar content of 50 per cent. At 1345° C, body No. 6, consisting of 30 per cent feldspar and 30 per cent flint, is most rigid. Of considerable interest in this set of curves is the fact that three distinct viscosity stages are recognized. At first, softening is observed which at from 1295 to 1315° C changes to a state of rigidity, since no further elongation is noted. This condition remains constant up to 1345° C, from which point on a decided loss in rigidity is noted and the elongation becomes quite marked. This would seem to indicate further solution of flint and clay by the feldspar, resulting in a viscous magma able to resist deformation. At 1345° the temperature, however, is sufficiently high to bring about softening of the entire mass. According to the viscosity attained between

about 1300° and 1345° three classes of bodies may be recognized, comprised, respectively, of No. 6, Nos. 7 and 8, and No. 9. The first of these evidently is the most, the last the least rigid within this temperature range.

In the 45 per cent clay series the lowest viscosity (greatest degree of softening) at the maximum temperature appears with 35 and 40 per cent feldspar, the least with 30 and 50 per cent. The body containing 55 per cent of feldspar is in the intermediate position as far as this point is concerned. The greatest degree of early softening is shown by Nos. 12 and 14. The most rigid body up to 1345° is No. 11, and hence it would appear to be the safest as far as deformation is concerned, within the temperature range indicated. A shorter zone of zero deformation increase is shown by Nos. 12 and 14. The three viscosity stages mentioned above are again noted in this series. Between about 1300 and 1345° three classes of bodies may be observed, namely, those of minimum viscosity, Nos. 11 and 13, of intermediate viscosity, No. 10, and greatest viscosity, Nos. 12 and 14.

The far-reaching effect of higher clay content is at once noted in the 50 per cent clay series. At 1380° Nos. 15, 16, and 17 reach the greatest degree of softening corresponding to an elongation of 1.2 per cent, which is very much less than the maximum value for the other series. The system, therefore, by the further addition of clay has become as a whole very much more rigid. The smaller degree of softening is shown by Nos. 15 and 18. The body containing 50 per cent feldspar is decidedly more viscous than the others containing flint. These two bodies and No. 13 are the ones showing least deformation of the entire series of 18 bodies. We again note the three viscosity stages observed in the preceding series and two classes of bodies, Nos. 15 and 18, and 16 and 17.

Collecting the bodies showing the greatest rigidity or viscosity at 1345°, we have the following compositions:

Number	Clay	Feldspar	Flint
	Per cent.	Per cent.	Per cent.
6	40	30	30
11	45	35	20
13	45	50	5
15	50	30	20
18	50	50	.....

SUMMARY.

Throughout these series the effect of higher feldspar content was to increase viscosity in a very marked degree, especially in the case of the low clay bodies. This is shown by a comparison of the elongation observed in the first paper published, using a load of 5 pounds per square inch, with that observed in the present work, employing a load of 14.5 pounds per square inch. Thus a body with 40 per cent clay and 25 per cent feldspar under a stress of 5 pounds per square inch showed at 1310° an elongation of 7.62 per cent, while one with 40 per cent clay and 30 per cent feldspar, with a load of 14.5 pounds per square inch, resulted at 1315° in an elongation of only 0.8 per cent, indicating a viscosity about 11.8 times as great. A slight decrease in viscosity is noted in the 40 per cent clay series when all of the flint is replaced by feldspar. With 45 per cent clay, 35 and 40 per cent of feldspar are most effective in decreasing the viscosity, but higher percentages again increase it. A still higher clay content causes the softening effect of the feldspar to diminish decidedly. Flint in such high feldspar bodies does not seem to be an important factor in governing the viscosity. The greatest rigidity is evidently due to the large clay content, and hence for high temperature porcelains high clay content is essential.

The function of viscosity is not a continuous one. After attaining a certain degree of softening a well-defined rigid state ensues which does not tend to approach further softening until a temperature of 1345° has been reached. Beyond this point the second stage of decided softening is entered upon. Although showing the same degree of viscosity at 1388°, bodies may be divided into several classes, according to the degree of softening observed between about 1300° and 1345°, which seems to be the most useful criterion. High clay bodies having feldspar as the only other constituent show very great viscosity. The most viscous bodies have been assembled.

The results should be of some service in the selection of bodies least subject to deformation in the firing process.

WASHINGTON, June 15, 1915.

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